Minutes & Slides from Proton Driver RF Meeting March 30, 2004

(G.W. Foster)

Subject: the 805 MHz fast phase shifter and related topics.

Attendees: Steve Hays, V. Kashikhin, Dave Wildman, Pierre Bauer, Al Moretti, Markus Huening, Brian Chase, Ding Sun, GW Foster, Milorad Popovic, Bob Kephart.

****NO MEETING NEXT WEEK** (TESLA Collaboration meeting)**

**** Next Meeting April 13th ****

MINUTES

1) Dave Wildman presented results on loss (Q) measurements of the existing YIG tuner. The tuner contains 3 rings of the same (Trans-Tech G510?) YIG material ordered for our real tuners. It was was originally built as a shorted stub for a 159 MHz cavity tuner. When operated as a shorted-stub quarter-wave resonator, its frequency varies from 400-500 MHz depending on magnetic bias field (see data on next pages). Dave's feeling (agreed to by those present) was that this pretty much replicated the field pattern expected in the 805MHz shorted stub tuner, so the Q measured in this tuner could be used to estimate the losses in one stub of the E-H tuner. The Q increased rapidly as the bias field was increased, and Q was above 2,000 for H>600 Gauss. [We plan to operate in the range 900 < H < 1500 Gauss]. Since an all-copper cavity of these dimensions would also be expected to have a Q of a few thousand, this indicates that the YIG losses were of the same order of magnitude, which is extremely good news. Dave's quick estimate was that this translated to <25W of average power dissipation in the YIG in our final tuner design. This should not be a problem either RF efficiency or for heat removal. By next week we could have some simulation results on what fraction of the cavity Q could be attributed to copper vs. ferrite.

2) Vladimir Kashikhin presented a status report of his investigation of bias coils and flux return shapes. He was able to achieve a 5% field uniformity in the YIG by covering the end of the shorted stub completely with a flux return cap plate made of Bsat=0.4T soft ferrite, putting a ferrite flux return tube around the solenoid, and extending the solenoid a few inches in front of the beginning of the YIG ferrite. A representative coil design (see his attached slides) requires 14kA-turns and consumes ~25W average. Removing the flux return tube still provides reasonable field quality but requires 17kA-turns. If the field quality spec is relaxed, the coil could be shortened and the Amp-turns and power reduced.

   The question of whether a solid conductor for the coil will be sufficient depends on the drive waveform. If the waveform is a simple pulsed ramp, solid conductor should be OK. However if the tuner feedback loop is thrashing around continuously every few microseconds, the skin losses will increase and this might argue for some sort of Rutherford cable or Litz wire or similar. Vladimir is looking into whether he can get his hands on leftover copper Rutherford cable used for a pulsed magnet in the Tevatron.

So it appears that we are looking at roughly:

(25W in the YIG) + (25W in the drive coil) = 50W per stub or 100W per tuner, for a coil with Bmax~1.5kG and a slew rate of 3 Gauss/microsecond in the YIG.

3) Steve Hays indicated that a +/-250V 100A pulsed mode could basically be provided with existing equipment, albeit with uncomfortably small operating margins. Vladimir has also worked out a +/-100V 250A coil design which might be preferable. The closed loop response would be limited by the 40KHz switching frequency of the existing supply module. Faster versions using FETS in place of IGBTs could eventually be considered.

4) **No Meeting Next Week** (see note at top). On thing to think about in the interim is what test procedures (and any new equipment?) are necessary to make the test-stand measurements needed to convince ourselves that both the stub and the tuner is doing what we need it to do. How about a pair of high-quality high-power adjustable-length coax shorting stubs that we could drop in place of the coax tuners for a reference?

ATTACHMENTS:

1) Dave Wildman’s Q Measurements (appended below)
2) Vladimir Kashikhin’s magnetic field analysis (separate file)

FERMILAB ENGINEERING NOTE

SECTION	PROJECT	SERIAL-CATEGORY	PAGE

SUBJECT: 159 MHz Cavity Tuner ($\lambda/4$ mode)

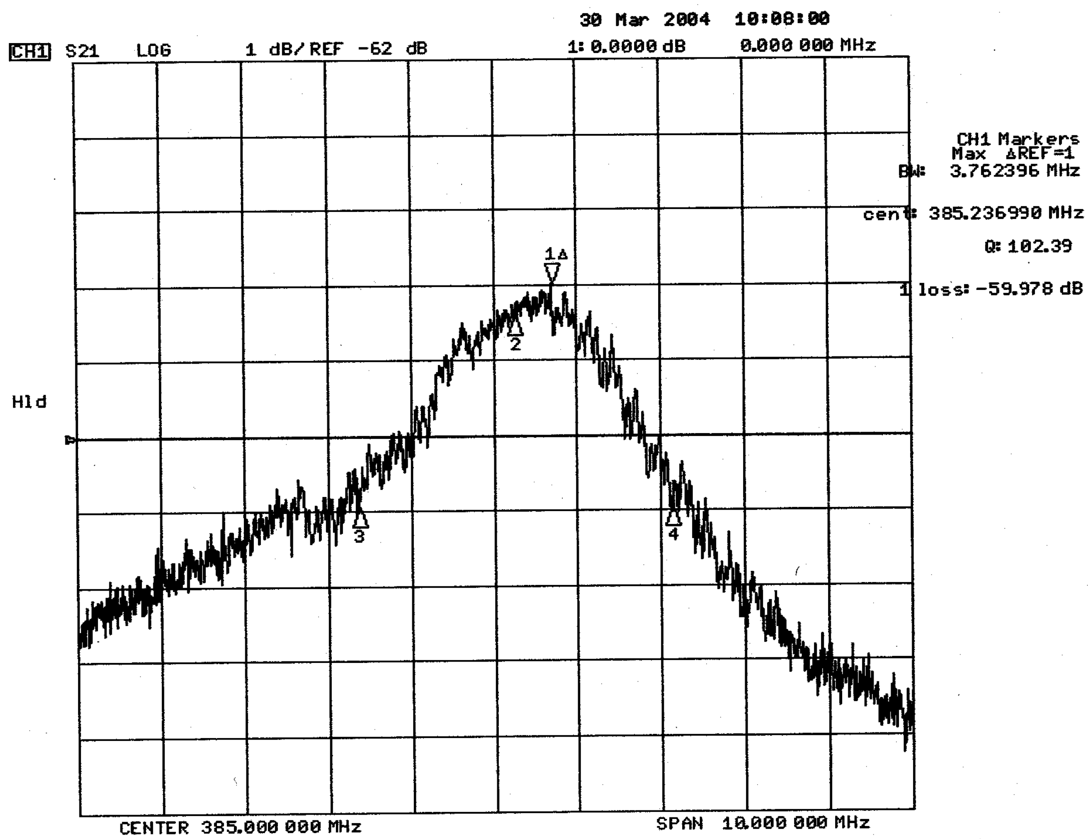
NAME: Wildman

DATE: 3/20/04

REVISION DATE:

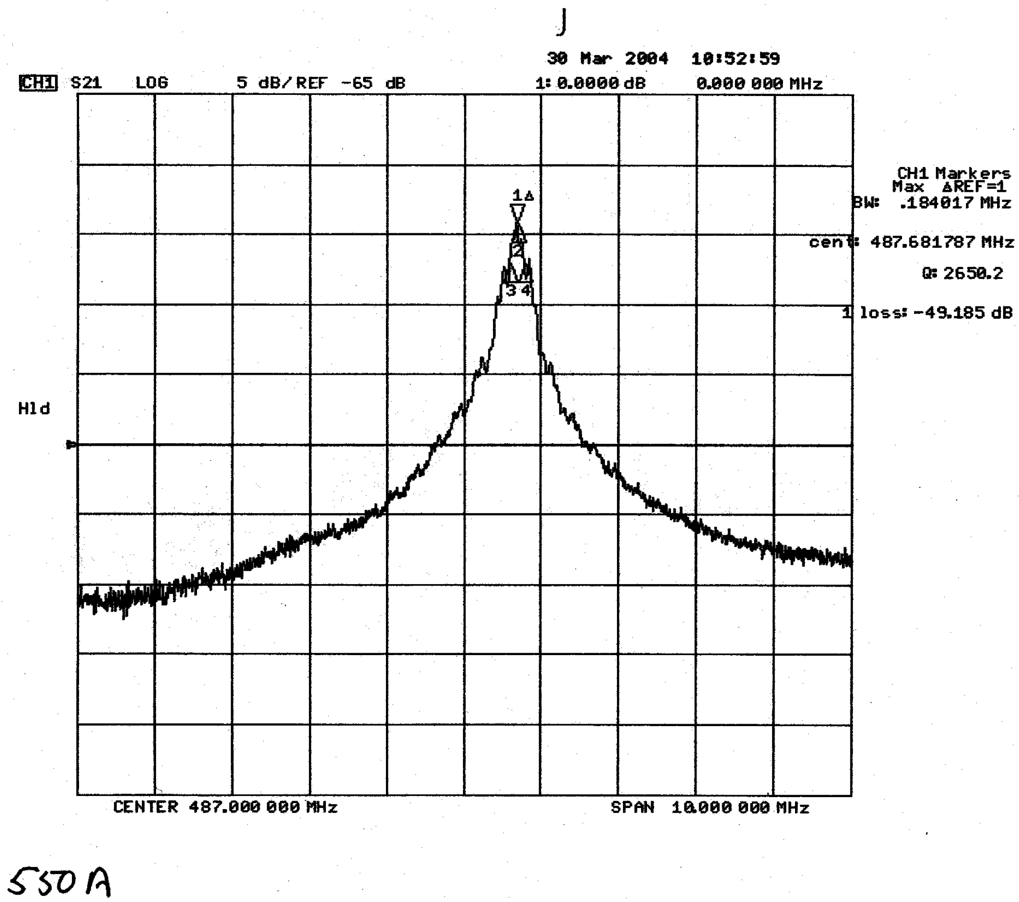
I (amps)	H_{max} (gauss)	Q	freq (MHz)
340	476	102	385
350	490	234	394
375	525	838	410
400	560	1176	425
450	630	2149	450
500	700	2328	471
550	770	2650	488
600	840	—	499
750	1050	—	526

Dave's measurements of Q vs. bias field for existing YIG tuner. Above 550A the power supply regulated badly and no useful linewidth measurements were possible.



~ ~~370~~ A
340

RESONANCE AT 340 Amps (476 Gauss) Freq = 385 MHz, Q=102.4



RESONANCE AT 550 Amps (770 Gauss) Freq = 488 MHz, Q=2650

Solenoid Geometry and Parameters

V.S.Kashikhin, March 30, 2004

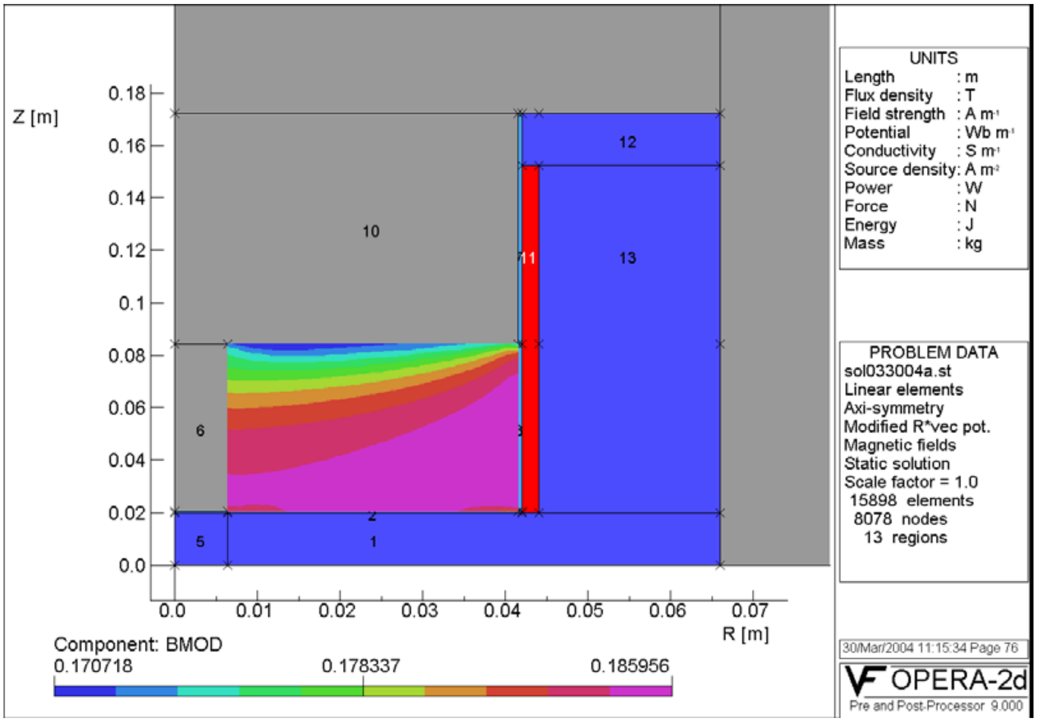


Fig. 1. Bias field homogeneity in YIG ferrite. Total current 17 kA. Energy 7.9 J.

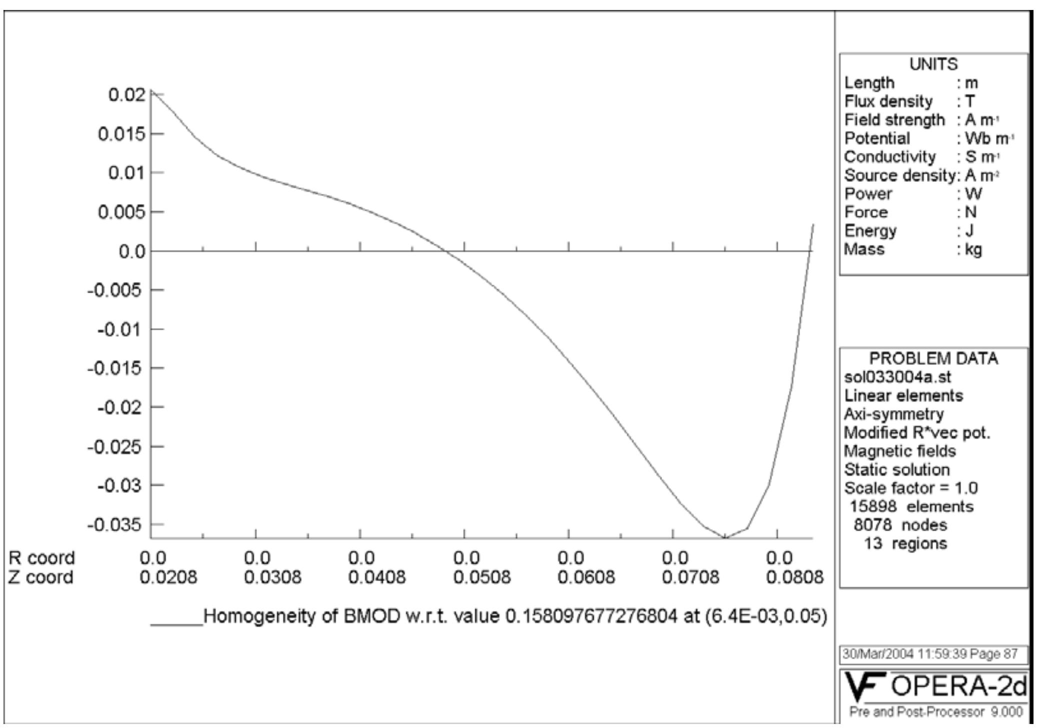


Fig. 2. Bias field homogeneity along Z axis at inner radius in YIG ferrite

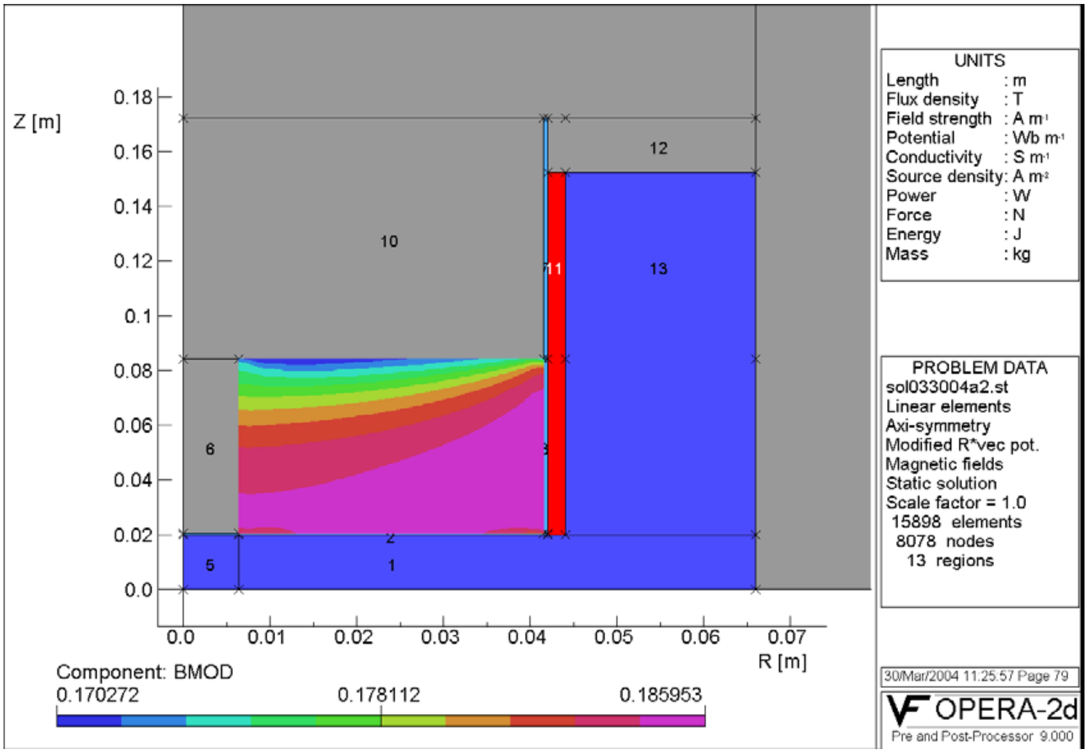


Fig. 3. Bias field homogeneity in YIG ferrite. Total current 17 kA. Energy 7.8 J

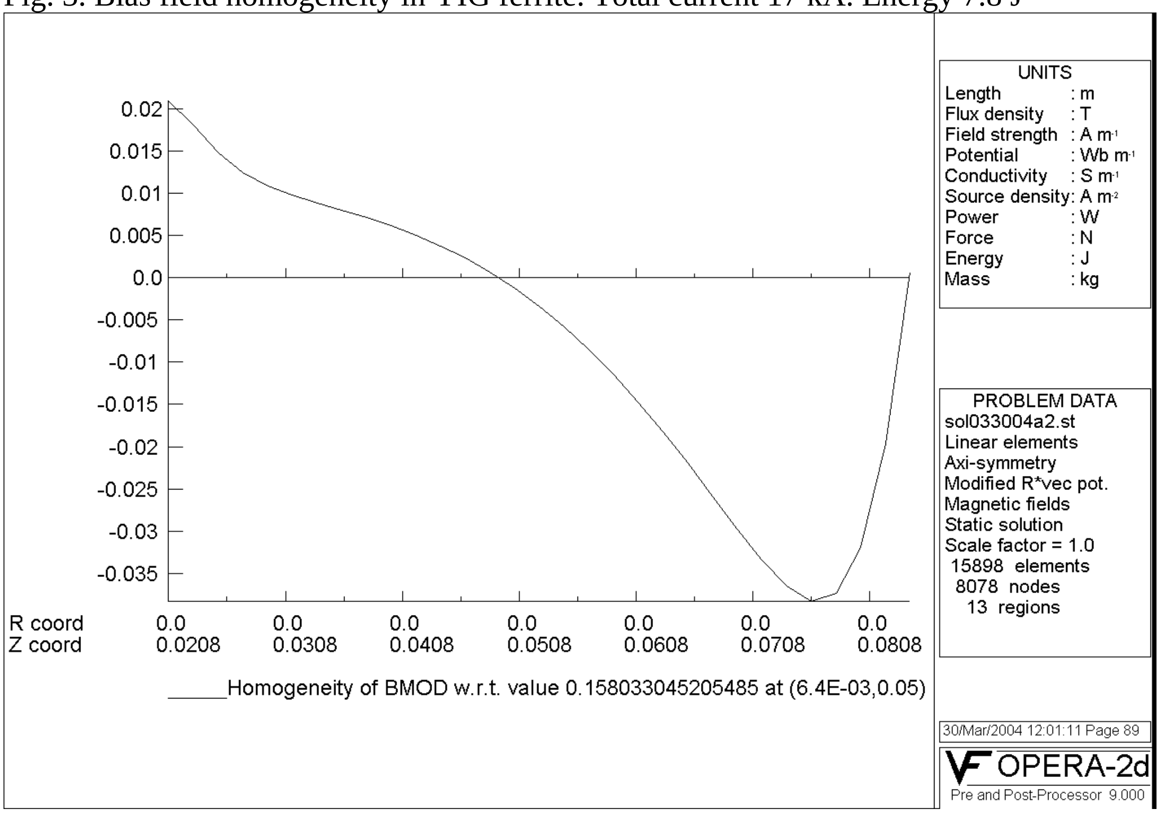


Fig. 4. Bias field homogeneity along Z axis at inner radius in YIG ferrite

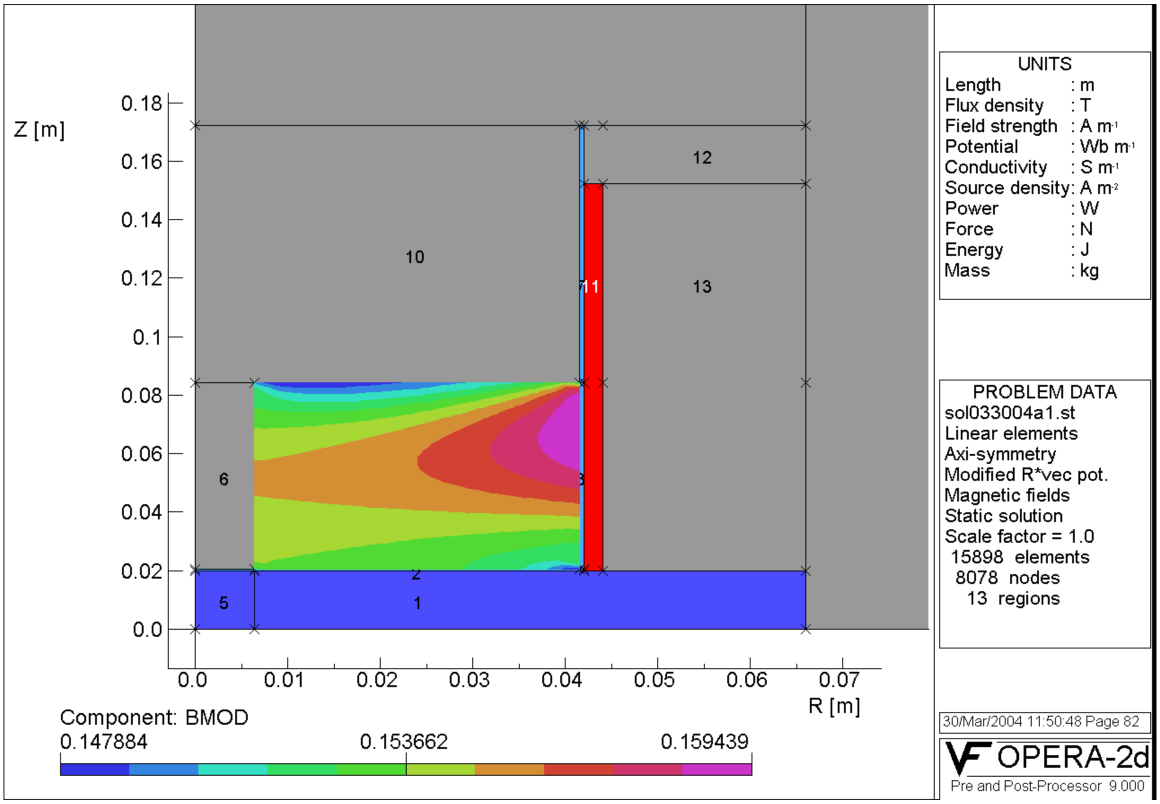


Fig. 5. Bias field homogeneity in YIG ferrite. Total current 17 kA. Energy 6.6 J

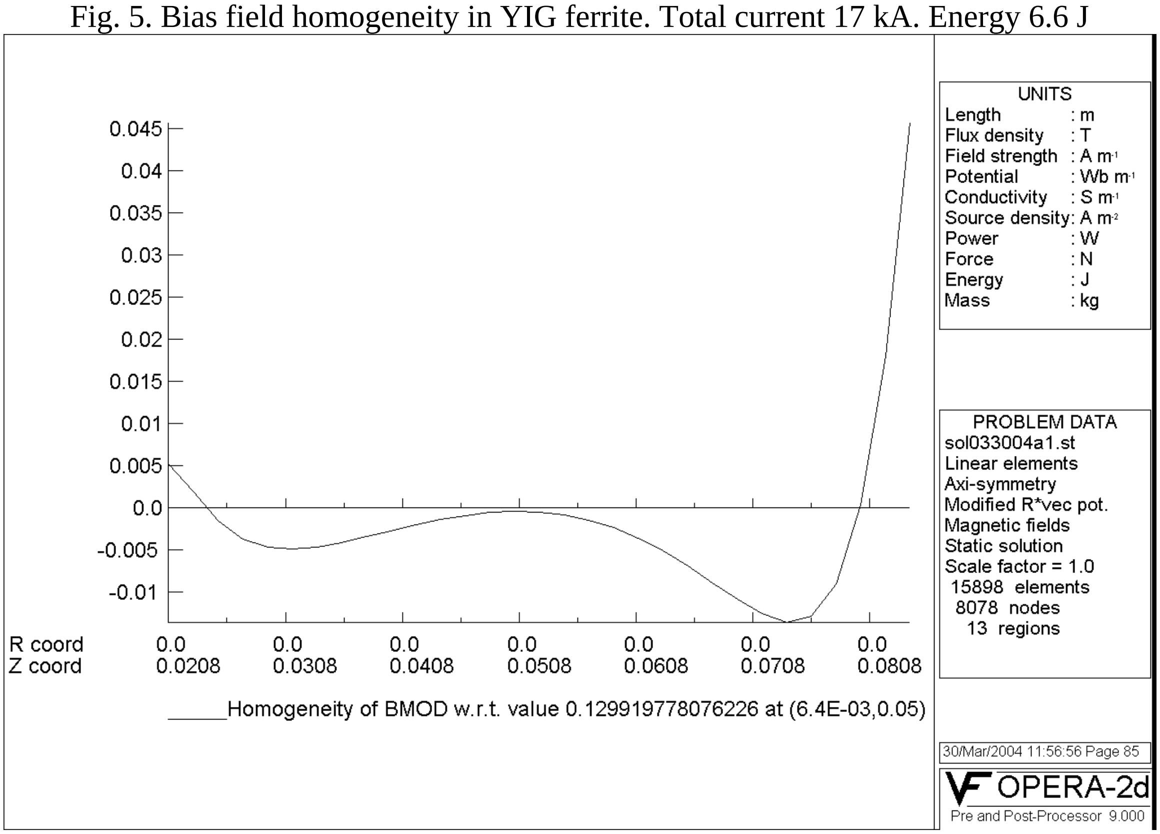


Fig. 6. Bias field homogeneity along Z axis at inner radius in YIG ferrite

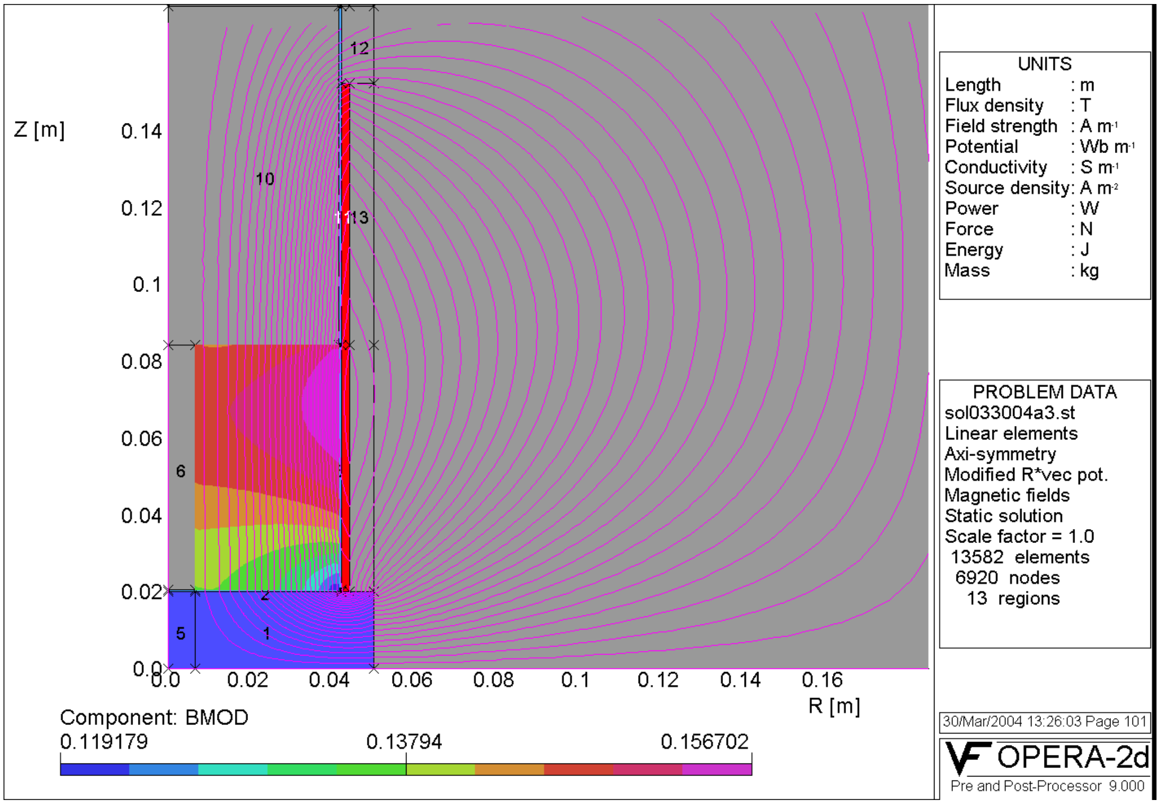


Fig. 7. Bias field homogeneity in YIG ferrite. Total current 17 kA. Energy 6.5 J

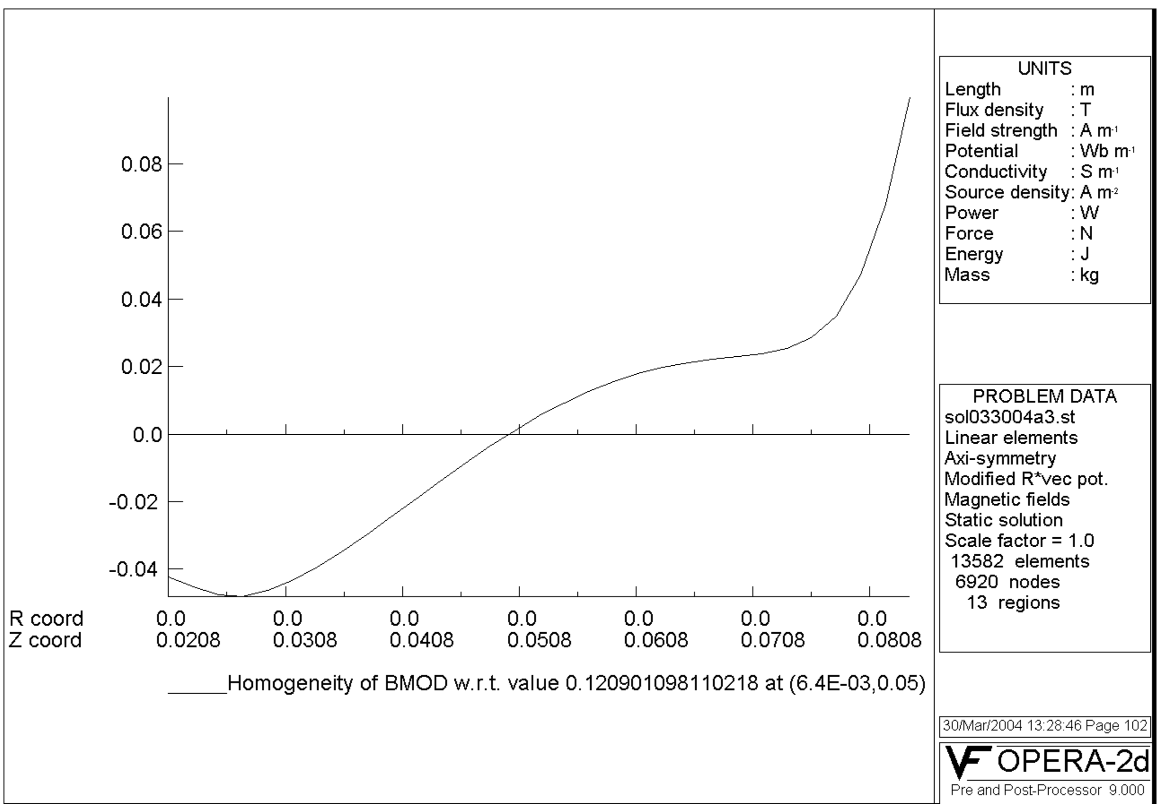
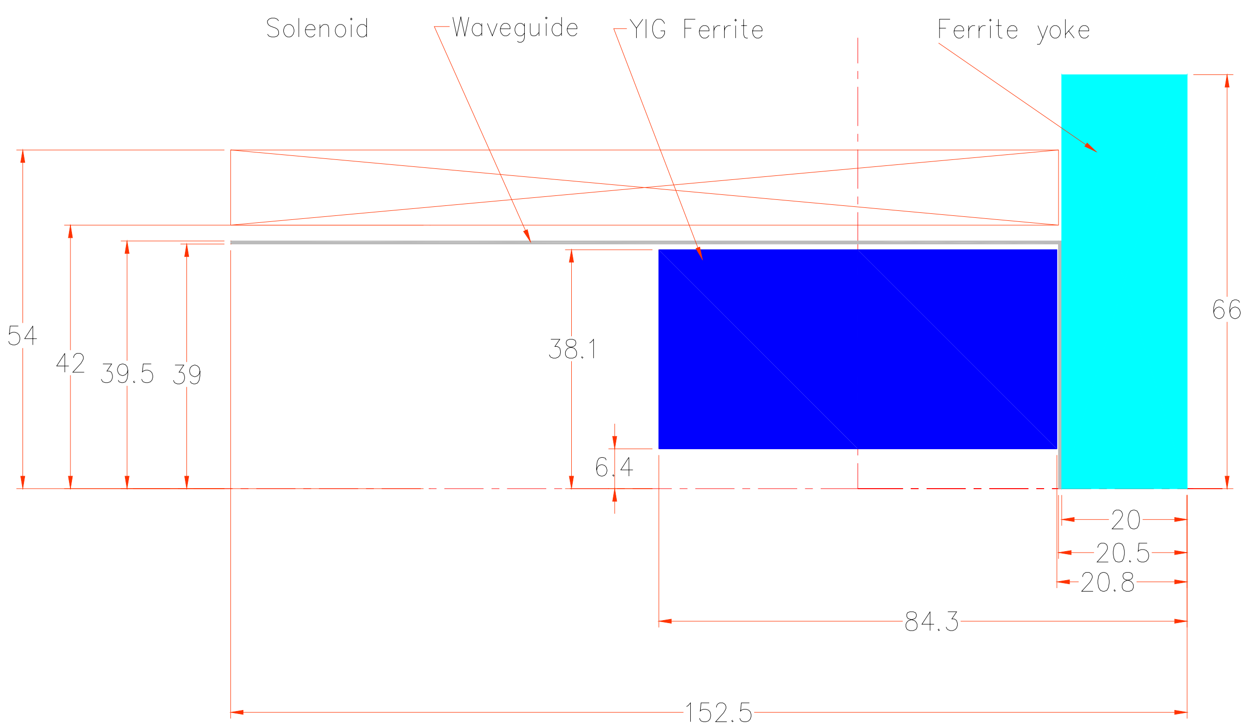


Fig. 6. Bias field homogeneity along Z axis at inner radius in YIG ferrite

Solenoid parameters (without flux return)

Bias field	0.15 T
Inductance	0.14 mH
Total ampere-turns	17320 A-t (no flux return)
	(~14000 A-t with flux return)
Current	321 A (no flux return)
	(~260A with flux return)
Resistance DC	16 mOhm
Resistive voltage	5 V
Conductor copper	28 strands of 1 mm diameter
Conductror copper area	22 mm^2
Number of turns	54
Number of layers	6 or 1 depending on technique
Inductive voltage for dB/dt=3 gauss/usec in YIG	90 V
Power losses	25 W
(at 1.5% duty cycle)	



Summary

The solenoid can be wound from Rutherford type of copper cable produced on TD cabling machine. No changes of tuning are needed. Such cable was used for the Tevatron air core pulsed quadrupole. Strands are insulated to eliminate eddy currents. After winding the coil should be vacuum impregnated together with the outer stainless steel cooling pipe forming rigid mechanical structure. Only small diameter hole needed in the ferrite end plate to organize the longitudinal cooling channel for YIG ferrite.

Solenoid calculated to generate 0.15 T field without outer ferrite core. During experiments the ferrite core can be added to compare both options.